CFP0906/US

CRF-210/222/276

BIF022062US

PATENT OF INVENTION

APPLICANTS

François THOUMY

Philippe LE BARS

Samuel ROUSSELIN

Lionel LE SCOLAN

Frédérique EHRMANN

TITLE

"Device and method for the dynamic allocation of frequencies for multicarrier modulation systems"

The invention relates to the field of methods for the transmission of information in the form of a signal, in particular an electromagnetic signal. It concerns more particularly the allocation of carrier frequencies for transmission systems using a modulation of the multicarrier type. It also relates to the choice of process for reducing the ratio of peak amplitude to mean amplitude usually required in transmission systems using multi-carrier type modulation.

It will be recalled that an information transmission system in general terms sends symbols (each symbol being for example a sequence of binary data) to be transmitted serially, thus occupying a frequency band which must necessarily be larger than the inverse of the duration of a symbol. When the symbol transmission rate becomes to high, it is impossible to guarantee that the channel will have identical amplitude and phase characteristics over the entire space of the frequencies constituting the passband. These distortion give rise to interference between symbols, which must be combated with a device known as an equaliser, which is relatively complex.

One possibility for avoiding this problem is to distribute the signal (formed by the stream of symbols) to be transmitted over a large number of parallel carriers, individually modulated at low transmission rate. Because the transmission rate is low for each carrier, the passband required is smaller and therefore it is probable that the frequency and phase characteristics will be identical for all the frequencies constituting this band.

This technique is called frequency division multiplex, the position of the carriers being chosen so as to avoid interference between them. A particular case is then Orthogonal Frequency Division Multiplex, or OFDM according to the term currently used by persons skilled in the art, for which the spacing between two adjacent subcarriers (the closest subcarriers in terms of frequency) corresponds to the inverse of the duration of a symbol sent.

However, as a result of flaws in the transmission channel, a transmitted symbol can be erroneously evaluated on reception. This drawback

can be highly prejudicial and demand, if it is, in fact, detectable, costly retransmission procedures.

To improve this situation, it is possible to transmit, not the sequence of information itself but a series of blocks of symbols, each of these blocks being the discrete, possibly inverse, Fourier transform of a corresponding block of information symbols.

The advantage of this procedure in the event of a transmission defect on the channel is that all of the symbols received will be affected by a small evaluation error. If the procedure were not applied, a single symbol would be affected by a large evaluation error, capable of leading to erroneous detection. It is hoped that each of the symbols will be correctly evaluated thanks to the symbols of the Fourier transform that are correctly demodulated.

The technique just described falls into the category of Orthogonal Frequency Division Multiplex, or OFDM, methods according to the term commonly used by the man of art. To appreciate the equivalence of this technique to OFDM strictly speaking, reference can be made, for example, to chapter 15 of the book entitled Modern QAM by Webb Hanzo.

This method of modulation, abbreviated to OFDM in the remainder of the text, is applied as follows : a complex vector comprising n components for transmission (for example, as traditionally known to the man of the art, complex numbers forming part of a whole creating an alphabet, or code, of the complex scheme adapted to correspond to the different sequences of data for transmission) is transformed with an inverse Fourier transform (IFFT), ie. by a matrix product of an inverse Fourier transform matrix (referred to, for the sake of simplicity, as a « Fourier matrix ») into n rows and n columns by the vector of the n data elements for transmission. The alphabet is generally that of the phase and amplitude modulations.

From this matrix product results a vector, referred to as a « transformed vector », of n complex numbers, which form a succession of numbers the amplitudes of which are transmitted successively by the device.

This series of amplitudes corresponding to a sequence of n data elements for transmission is referred to as a baseband OFDM symbol.

This signal can itself modulate a carrier of a higher frequency to be able to be transmitted in a transposed band, according to a conventional technique.

Baseband reception or demodulation is carried out through multiplication of the transformed vector received by the matrix of the direct Fourier transform (or the matrix of the inverse transform if use has been made of a direct transform on transmission). The received vector is the image of the vector obtained from OFDM transmission, but modified in that it has passed through a communication channel in which it has been subjected to interference, noise addition or partial fading.

OFDM demodulation does not, therefore, restore the initial components of the complex vector associated with the sequence of data for transmission, but approximate components, in fact. The information is restored after a decision making process which consists of measuring the distance of each component calculated after reception at each point of the encoding alphabet used for transmission, and of assimilating the component calculated after reception to the point of the alphabet that corresponds to the shortest distance.

Instead of having most of the data received perfectly and a few data elements completely lost, as in conventional series transmission, the transmission errors are, in fact, distributed over all of the points, which ensures that it is almost always possible to reconstitute the initial information in its entirety.

This conventional mode of transmission using OFDM does, however, have a major drawback. The discrete Fourier transform creates (through the effect of the matrix product) a linear combination of the n symbols for transmission and a number of critical complex vectors, associated with critical sequences of data, can result, after the Fourier transform, in transformed vectors whereof the succession of amplitudes of the components has local

maximum values (then corresponding to signal peaks) that are very substantial, in relation to the mean value for the amplitudes of the said components of the transformed vector.

The peak amplitude to mean amplitude ratio of the transformed vectors corresponding to these critical sequences (or, in an equivalent manner, to these critical complex vectors) is thus very high.

Such critical sequences cause difficulties for the downstream devices as, in practice, an amplifier or a modulator lack fidelity in restoring swift variations of high amplitudes. This is then reflected in clipping, namely non-transmission of the signal peaks, hence the loss of the corresponding information. Furthermore, this introduces harmonic distortion, which is one of the major problems with transmission systems, as it is impossible to cancel out.

Theoretically, maximum amplitude is demonstrated to be a direct function of the length of the sequence of symbols for transmission.

It is thus highly desirable to reduce this maximum amplitude so as to use the full dynamic properties of the amplifiers without causing clipping or distortion. Several solutions aimed at alleviating this problem of peaks have been described. One of these techniques is to exclude sequences of symbols creating maximum peak-to-mean amplitude ratio values of the OFDM symbol. This is achieved by encoding, introducing redundancy, hence a reduction in the transmission rate of useful symbols. One example of implementation of this solution is set forth in US patent 5 636 247 issued to Lucent Technologies Inc.

Another solution is to calculate the inverse Fourier transform for the sequences of symbols to be transmitted, and then to measure the peak-to-mean ratios for the transformed vectors thus obtained, and, by looping, to change the phases of the components of the critical complex vectors corresponding to the peaks. Measurement of these peaks involves calculating another discrete Fourier transform. A technique of this kind is disclosed in US patent 5 610 908 issued to British Broadcasting Corporation. A third solution is to change the coefficients of the Fourier matrices (inverse and direct) so as to avoid or limit the occurrence of these peaks. This process induces a slight

deterioration in the bit error rate. By way of example, one solution of this type has been proposed by Canon (French patent application FR 98.13261).

All these solutions currently implemented have the drawback either of adversely affecting the bit rate of the transmission or of impairing the quality of the said transmission, or again, of being complicated.

A multicarrier transmission system of standard type (see Figure 1) has a data source 10, a serial-to-parallel converter 20 connected to a stream of subcarriers, and a multicarrier modulator 50 which transmits the data to an RF transmitter 60. In a standard system of this type, the data are distributed sequentially over the different subcarriers. For example, for a system using eight subcarriers, the data bearing the numbers 0, 8, 16, 24 will be transmitted over the subcarrier 30 of frequency ω_1, the data bearing the numbers 1, 9, 17, 25 will be transmitted over the subcarrier frequency ω_2 etc.

It happens that the majority of the transmission channels used (and notably the so-called "radio" channels) have transmission characteristics (attenuation, noise, phase displacement etc) which are variable according to the carrier frequency used. Certain channels have characteristics which are variable over time, for example because of so-called "multipath" effects, because of elements entering the channel, etc.

Figure 2 presents an example with a symbolic representation of the transmission quality (signal/noise ratio SNR) on each of the subcarriers in the case of eight subcarriers, at two different times $t = t_1$, and $t = t_2$. The transmission characteristics for each frequency varying with time, it is found in the example that the data item X_6 is correctly transmitted at time t_1, but may be erroneous at time t_2.

The concept of efficiency of such a multicarrier transmission is then related to the resolution of the following problem: with what power P must transmission be carried out in order to ensure the transmission of a certain output of data D with a quality Q in a given physical transmission channel?

This efficiency can be defined as the ratio

(transmission rate x quality) / emitted power

The solution generally adopted for this problem of transmission efficiency is a compromise between on the one hand the energy emitted during transmission over the transmission channel and on the other hand the acceptable error rate for the transmitted data.

The operating principle of the majority of existing devices is to increase the transmission power in order to counteract the degradation of the transmission channel and to transmit all the data with guarantee of an error rate below a predetermined threshold.

Several techniques have been disclosed for improving the efficiency of transmission.

These techniques are based on a different coding for the data considered to be the most significant, before sending over the transmission channel.

A technique disclosed in US patent 5 425 050 introduces a concept of pyramidal coding, proposing the idea of creating two classes of data requiring two different transmission quality levels.

US patent 5 467 132 describes a method for coding the data differently according to their significance.

Other techniques are based on a dynamic estimation of the transmission quality on each subcarrier, and on a modification of number of bits per symbol transmitted in order to take account of this variation in transmission quality (in particular US patent document 5 479 447 can be cited).

In summary, the conventional solutions to this problem of multicarrier transmission efficiency are:

- increasing the transmission power so as always to transmit with a sufficient signal/noise level,

- testing the transmission channel and eliminating the subcarriers most interfered with,

- adding redundancy to the data by coding,

- modifying the number of bits per symbol for the subcarriers interfered with.

All these solutions result in an increase in the emitted energy for transmitting the same data stream with a constant quality.

The present invention sets out to propose a new method of transmitting information using a multicarrier modulation, this method having better transmission efficiency.

According to a second objective of the invention, the latter also uses the noisy carriers, usually rejected by conventional techniques.

According to another objective, the invention proposes a dynamic transmission method which makes it possible to preserve optimum efficiency when there are variations in characteristics of the transmission channel.

Another objective of the invention is to guarantee correct transmission of the most significant data, simply to a sufficient signal to noise ratio (SNR).

Another object of the method is to reduce the emitted energy during transmission, compared with the existing techniques, for equal efficiency.

To this end, the invention proposes under a first aspect a method of transmitting data using a modulation of the multicarrier type, comprising operations of :

- extraction from received data of a first signal representing the transmission quality on each sub-carrier observed and transmitted by a remote device;

- allocation of transmission data to the sub-carriers in an order based on significance of the transmission data and the first signal representing the transmission quality, and

- insertion in transmission data of a second signal representing the order in which the transmission data are allocated to the sub-carriers based on the significance of the transmission data and the first signal;

It will be understood that this method takes account of the significance of the data, not at the time of coding, but at the time of allocation of a transmission frequency, in an adaptive fashion, when the reliability of the carriers (error rate during transmission) varies, and by taking advantage even of the very noisy carriers, for transferring data of lesser significance. This possible use of the noisy carriers affords a gain in efficiency compared with conventional techniques, in which these carriers would have been avoided, and in which a single error rate common to all the data transmitted is defined in advance.

In addition, the dynamic character of the method guarantees that, in the event of high degradation of the reliability of the transmission channel, the most significant data will always be transmitted as a priority (that is to say over the most reliable channel) with the greatest possible quality at this moment.

Taking into account the significance of the data gives a good saving in energy compared with current methods since in this way it is possible to reduce the transmission power without impairing the quality of transmission of the significant data, and therefore without any risk of loss of the substance of the message.

This is an improvement compared with the current methods in which transmission is carried out with sufficient transmission power to guarantee a given signal/noise level (SNR) for all frequencies used.

Similarly, the invention proposes a method of receiving data using a modulation of a multicarrier type, comprising operations of :

- analysis of transmission channel so as to supply a signal representing transmission quality of each sub-carriers in a return direction;

- extraction from received data of a signal representing an order in which the transmission data are arranged by a transmission device on the sub-carriers; and

- formation of the received data according to the signal representing the order in which the transmission data are arranged by the transmission device.

According to a preferred implementation, the received data are serialized in said formation operation according to the signal representing the order.

The invention also relates to a device for transmitting data to a remote device, comprising :

- means for allocating the transmission data to the sub-carriers in an order based on significance of the transmission data and transmission quality of the sub-carriers; and

- means for inserting in the transmission data of a signal representing the order in which the transmission data are allocated on the sub-carriers based on the significance of the transmission data and the transmission quality of the sub-carriers.

According to a preferred implementation of this device, said allocating means allocates the transmission data to the sub-carriers in the order based on the transmission quality of the sub-carriers observed and transmitted by a reception device.

According to a preferred implementation, the device comprises premodulator means including :

- a means of presenting, to the different inputs of the modulator, each input corresponding to a subcarrier, different data to be transmitted according to a classification of their significance as well as the transmission quality level of each subcarrier in the "outward" direction A $\rightarrow$ B,

- a means of inserting in the data to be transmitted a signal representing the transmission quality observed in each subcarrier in the "return" direction B $\rightarrow$ A,

- and a means of inserting, in the data, a signal representing the order in which there are arranged the different data to be transmitted at the input of the premodulator,

and the device also has:

- a post-demodulator means including:

- a means of extracting, from the signal issuing from the demodulator, an FCD signal representing the transmission quality observed by the remote device B on each subcarrier in the "outward" direction A $\rightarrow$ B, said signal being generated by the remote device B,

- and a means of analysing the transmission channel so as to supply the signal representing the quality of the transmission of each subcarrier in the "return" direction B $\rightarrow$ A,

- a means of extracting, from the signal issuing from the demodulator, a signal representing the order in which there were arranged the different data to be transmitted at the input of the premodulator of the remote device B,

- and a means of serialising the data received as a function of the DP signal representing the order in which there were arranged the different data to be transmitted at the input of the premodulator of the remote device B.

According to a preferred implementation, the premodulator means also includes a data classification unit and a frequency allocation unit.

According to a particular characteristic, the unit for classifying data to be transmitted has means adapted to generate a DS signal representing the significance of each data item supplied by the source.

According to another particular characteristic, the frequency allocation unit has means adapted to generate a data allocation command signal (determining the distribution of the data over the different subcarriers), from data including the DS and FCD signals A $\rightarrow$ B and means adapted to generate a signal representing the order in which there are arranged the different data to be transmitted at the input of the premodulator.

According to a particular characteristic, the frequency allocation unit has means adapted to perform operations of:

- initialisation, in which the frequency allocation unit reads the information contained in the FCD, DS and storage signals,

- classification of the subcarriers by order of interference and storage in the table thus obtained,

- classification of the indices of the data to be transmitted in order of significance, using the information contained in the DS signal, and storage of the result of this classification,

- transmission of the signal of the relative positions of the data with respect to each other, to the unit for insertion in the data to be transmitted,

- transmission of the data allocation command signal to the data allocation unit, this DAC signal being in fact composed of pairs (subcarriers, index of the data),

- testing to check whether all the pairs have been supplied, so that, if the test is negative, the following pair is supplied, and if the test is positive, the initialisation step is returned to.

According to yet another particular characteristic, data allocation unit has means adapted to transfer each data item supplied by the source to the subcarrier defined by the frequency allocation unit in the data allocation command signal .

According to a particular characteristic, the device for the transmission of data from a device A to a remote device B via a transmission channel, has a CPU calculation unit, a temporary data storage unit, a program storage unit, character entry means, image reproduction means and means allowing inputs and outputs.

Under a second aspect, the present invention aims to provide a novel process for optimizing an information transmission system using multi-carrier modulation, the said process offering improved transmission efficiency.

For this purpose, the process for transmitting groups of data elements over a transmission channel using multi-carrier type modulation is wherein a significance is attributed to each data element or group of data elements for transmission, and the most important data is transmitted after modulation favoring a minimum bit error rate, the other data being transmitted after modulation favoring a maximum data rate.

It will be appreciated that, generally speaking, the invention aims to optimize the perceived quality of a transmission using OFDM modulation by exploiting knowledge of the importance of the data for transmission.

According to the nature of the data transmitted, an improvement in perceived quality can be obtained, in fact, either by increasing the data rate (thus by more quickly accessing the data in its entirety) or by reducing the bit error rate in the transmission of the said data.

One simple example of data that can be transmitted according to the invention is that of a picture having a subject and a background ; the subject has to be transmitted with the smallest possible bit error rate, whereas the background has be transmitted as quickly as possible.

The invention aims to perform a variety of OFDM transmissions involving minimization of the maximum value for the peak-to-mean ratios of the symbols transmitted, this minimization system being dynamically chosen from among known systems so as to optimize the perceived quality of the transmission.

The invention aims to produce a low-cost system that is simple to implement.

The invention applies to the communication system, i.e. it changes both the transmitter and the receiver.

The invention also relates to a process for transmitting data from a local device, A, to a remote device, B, via a transmission channel, local device A comprising a data source, two multi-carrier modulators, the first one being adapted to favor the minimum bit error rate and the second to favor the maximum data rate, multiplexers adapted to select a modulator, and a radiofrequency interface ;

wherein it comprises operations involving :

- receiving from the source a new succession of data elements for transmission ;

- extracting the information of importance that is associated therewith and analyzing this information ;

- if the data element is considered to be highly significant, inserting a « Most Significant Data » item of information and applying an algorithm that generates an OFDM symbol after the addition of redundancy bits that reduce the peak value of the signal ;

- if the data is considered to be less significant, inserting a « Least Significant Data » item of information and applying an algorithm that generates an OFDM symbol by using an inverse fast Fourier transform (IFFT) matrix modified so as to reduce the peak value of the signal;

- transmitting the OFDM symbol generated, via the RF interface.

In one advantageous form of embodiment, the step of inserting the item of information representative of the type of modulator chosen will be combined with the step of inserting synchronization data.

The invention also relates to a process for receiving data transmitted by a remote device, A, via a transmission channel, the reception device, B, comprising a radiofrequency receiver, two multi-carrier demodulators, the first one being adapted to favor the minimum bit error rate and the second the maximum data rate, multiplexers adapted to select a demodulator, and a unit for extracting the type of demodulator to use ;

wherein it comprises operations involving :

- the radiofrequency receiver receiving a new succession of data elements;

- extracting the information of importance that is associated therewith and analyzing this information ;

- generating a control signal representative of the type of demodulation to be applied ;

- if the data element is considered to be highly significant, applying a demodulation favoring a minimum bit error rate ;

- if the data is considered to be less significant, applying a demodulation favoring a maximum data rate ;

- sending demodulated data to the destination.

The invention also relates, according to another aspect, to a device, A, for transmitting data to a remote device, B, via a transmission channel, with device A comprising a data source and a radiofrequency interface ;

wherein the device according to the invention also comprises two multi-carrier demodulators, the first one being adapted to favor the minimum bit error rate and the second to favor the maximum bit rate, and multiplexers adapted to select a modulator, and an insertion unit responsible for inserting into the data an item of information representative of the modulator chosen according to a criterion of importance of the data received from the source.

According to yet another aspect, the invention relates to a device, B, for receiving data transmitted by a remote device, A, via a transmission channel, with reception device B comprising a radiofrequency receiver ;

wherein the reception device also comprises two multi-carrier demodulators, the first one being adapted to favor the minimum bit error rate and the second the maximum data rate, multiplexers adapted to select a demodulator, and a unit for extracting control data (type of demodulator to be used) and for generating a signal to command the multiplexers.

Under a third aspect, the present invention concerns a method and device for managing information transmissions in a communication network including a base station and at least one peripheral station communicating said information with it, notably by the transmission of several carriers modulated by the information.

From the document FR 2 660 131, a method and device are known for transmitting digital data over a communication channel, based on a technique of modulation by orthogonal frequency division multiplexing (OFDM).

This method starts from the principle that digital data from different sources require levels of protection against transmission errors which are different from one source to another and which are adapted to the type of information under consideration.

The method proposes, for a given group of carriers of an OFDM symbol, to select a type of modulation and a coding efficiency which are appropriate according to the interference affecting the communication channel and the protection level required.

In cases, for example, when it is wished for the data issuing from two sources to be transmitted simultaneously over a radio communication channel, the device proposed in this document allocates a group of given carriers to each of the sources and selects an appropriate modulation type and coding efficiency for each of the groups.

When this technique makes provision for increasing the coding efficiency or reducing the modulation level, for a data source, in order to increase protection against transmission errors, this will result in a decrease in the useful data transmission rate over the communication channel.

However, in certain applications of the real-time type, such as for example the transmission of video or audio data or data used for video conferencing, it is essential to guarantee a constant data rate, whilst the transmission error rate can vary.

Another document, US 5 726 978, describes a method of allocating carriers applied to modulation by orthogonal frequency division multiplexing (OFDM).

During transmissions of information between a base station and several peripheral stations in a network, this method recommends allocating a group of carriers of an OFDM symbol dynamically to the transmissions between the base station and a peripheral station.

According to the results of measurements of the noise level and the quality of reception of the OFDM symbols transmitted over the communication channel, the base station decides to replace some of the carriers which, for example, give rise to data transmissions affected by an excessively high error rate, with other carriers less affected by noise.

This method proposes above all to guarantee a low transmission error rate between the base station and the peripheral stations.

In the light of the above, the applicant realised that it would be advantageous to find a method and device for managing information transmissions which can adapt easily to the different requests coming from communication stations in a network and requiring a given service quality, in terms of transmission error rate and output to be transmitted, and making it possible, for example, to satisfy requests for which the transmission error rate must be low and where, at the same time, the useful output of data to be transmitted must remain substantially constant.

The invention aims to resolve under a third aspect this problem and thus proposes a method of managing information transmissions by radio between a base station and at least one peripheral station, communicating information with it by the transmission of carriers modulated by said information, said method including a step of allocating a number of carriers and a modulation to at least one radio communication channel allocated to the transmission of information between said base station and said at least one peripheral station, wherein said method includes a step of determining a number of carriers and a modulation adapted in response to a required service quality, in terms of transmission error rate and transmission rate, for a given transmission of information between said base station and said at least one peripheral station, the adapted number of carriers and modulation differing according to the required service qualities.

Thus the invention guarantees, for a given information transmission over a radio communication channel, a service quality in terms of required transmission error rate and transmission rate, choosing an appropriate pair consisting of a number of carriers and a modulation.

This is particularly important in applications of the real-time type (transmission of video data) or of the file transfer type.

When a transmission of information over the communication channel requires a service quality (in terms of transmission error rate and transmission rate) different from that allocated for the previous transmission of information, the invention makes provision for adapting, for this transmission of information, the number of carriers and the modulation guaranteeing this new service quality.

It should be noted that the transmission error rate can be interpreted in different ways: thus it can for example correspond to an error rate on the bits transmitted or on the number of video or audio data frames transmitted.

In the case of a transmission using a technique known as modulation by orthogonal frequency multiplexing OFDM, the transmission error rate can, for example, mean the error rate on the number of OFDM symbols transmitted.

Advantageously, the required service qualities are also expressed in terms of transmission error rate threshold and variation in the transmission rate acceptable for said given information transmission.

The decision on reconfiguration of the transmission parameters (number of carriers, modulation) is simplified because of the presence of a transmission error rate threshold.

Moreover, accepting that the transmission rate can vary within a range instead of requiring a single value makes it possible to limit the number of possibilities of reconfiguration of the transmission parameters and to be able to terminate a transmission in the even of non-compliance with this criterion.

According to a particular characteristic, the step of determining carriers and a modulation is performed during a transmission of information between the base station and at least one peripheral station, which is particularly advantageous when the actual transmission conditions on the communication channel vary during the information transmission itself, for example because of a movement of the peripheral station.

It should nevertheless be noted that the determination step can also be performed between two information transmissions.

In addition, it is advantageous to be able to perform this determination step both before a new transmission of information, in order to adapt to a new required service quality, and during transmission, in order to guarantee that this service quality is indeed complied with, even if the transmission conditions vary.

According to another particularly advantageous characteristic, the method includes a step of receiving at least one measurement of the transmission error rate on the radio communication channel allocated to the transmission of information between the base station and at least one peripheral station. This error rate is measured globally for the transmission between the base station and at least one peripheral station, and is subsequently taken into account for the step of determining a suitable number of carriers and a suitable modulation.

It should be noted that the step of receiving at least one measurement of the transmission error rate can be performed before or after the step of determining a number of carriers and a modulation suited to a required service quality.

According to a particular characteristic, after the step of receiving said at least one measurement, the method includes a step of analysing said at least one transmission error rate measurement and of comparing the result of this analysis with the service quality required in terms of transmission rate and transmission error rate.

According to one characteristic, the method includes a step of determining a step of determining a suitable number of carriers and a suitable modulation as a function of the result of the measurement, if the result of this analysis does not meet the service quality required for said transmission.

According to a particular characteristic, the method includes a step of determining a number of carriers to be allocated which is different from that which was previously allocated to said at least one communication channel between the base station and the peripheral station.

The number of given carriers to be allocated to said at least one communication channel between the base station and the peripheral station can therefore be greater than that allocated previously to this communication channel, for example in order to guarantee a required service quality in the case of an application of the real-time type where the transmission rate must remain constant.

According to another particular characteristic, which can be combined with the particular characteristic mentioned above, the method also includes a step of determining a modulation to be allocated to said at least one communication channel between the base station and the peripheral station which is different from the one allocated before.

Thus, where the given number of carriers is greater than the one allocated before in order to guarantee a required service quality (for example in the case of an application of the real-time type where the transmission rate is to remain constant, if, in addition, the communication channel is very noisy and if the required service quality demands a low transmission error rate, it is also possible to reconfigure the modulation in order to make it more robust.

The given number of carriers to be allocated to said at least one communication channel between the base station and the peripheral station can also be less than that allocated previously to this communication channel where the communication channel becomes less noisy.

Thus the carriers which are no longer used for this communication channel, because of the reconfiguration, can be allocated to another communication channel requiring an additional number of carriers.

According to another particular characteristic, which can be combined with the characteristic according to which the given number of carriers is less than the one allocated before to said at least one communication channel between the base station and the peripheral station, the method also includes a step of determining a modulation to be allocated which is different from that allocated before.

Thus, where the number of reconfigured carriers is less than the one allocated before, in order to guarantee a service quality demanded for this transmission, and where this service quality also makes it necessary to guarantee a constant transmission rate, it is also possible to reconfigure the modulation in order to make it less robust.

According to another advantageous characteristic, the method includes on the one hand a step of determining a number of carriers to be allocated to a first communication channel between the base station and a first peripheral station which is greater than that which was previously allocated to this first communication channel and on the other hand a step of determining a number of carriers to be allocated to a second communication channel between the base station and a second peripheral station, which is smaller than the one previously allocated to this second communication channel, in response to service qualities required respectively for the transmission of information over these communication channels, in the terms of transmission error rate and transmission rate.

Thus the step of determining a different number of carriers can result from a compromise between two communication channels, according to the service qualities required for the transmissions of information over each of them, in so far as the two communication channels do not simultaneously require a number of carriers greater than that previously effected.

Advantageously, transmission by modulated carriers uses a technique of modulation by orthogonal frequency division multiplexing OFDM. This technique has a spectral efficiency expressed in bits per hertz which is greater than the other modulation techniques.

Moreover, this technique constitutes an effective means for combating the effects of multiple propagation and fading.

This technique makes it possible to distribute the fading effects which are selective with regard to frequency of the transmission channel over a certain number of subchannels which have constant fadings corresponding to the carrier frequencies of the OFDM multiplex.

According to another aspect, the invention concerns a method of sending information over a radio communication channel including steps of allocating a number of carriers and a modulation to said information for transmitting these over the radio communication channel and sending said information in the form of carriers modulated by said information, wherein said method includes a step of reconfiguring the number of carriers and the modulation allocated to the information according to a required service quality, in terms of transmission error rate and transmission rate for a given information transmission, the number of carriers and the modulation reconfigured differing according to the required service qualities.

The step of reconfiguring the number of carriers and the modulation allocated to a given information transmission is performed so as to adapt to the required service quality.

According to yet another aspect, the invention relates to a method of receiving information coming from a radio communication channel, including a step of receiving said information sent in the form of carriers modulated by said information and a step of selecting the carriers and modulation allocated to said information, wherein it includes a step of reconfiguring the number of carriers and the modulation to be selected according to a required service quality, in terms of transmission error rate and transmission rate for a given information transmission, the number of carriers and the modulation reconfigured differing according to the required service qualities.

According to a particular characteristic, the method according to the invention includes a step of carrying out at least one measurement of the transmission error rate on the radio communication channel allocated to the information transmission in question.

Advantageously, the result of this measurement supplies information on the actual conditions of the current transmission and therefore makes it possible to reconfigure the number of carriers and the modulation allocated to this transmission where the required service quality is not met.

The actual conditions of the current transmission can therefore be monitored continuously and the number of carriers and the modulations adapted accordingly.

Correlatively with the management method, the invention relates to a device for managing the information transmissions by radio between a base station and at least one peripheral station communicating information with it by transmitting carriers modulated by said information, said device having means of allocating a number of carriers and a modulation to at least one radio communication channel allocated to the transmission of information between said base station and said at least one peripheral station, wherein said device has means of determining a number of carriers and a modulation adapted in response to required service qualities, in terms of transmission error rate and transmission rate for a given information transmission between said base station and said at least one peripheral station, the number of carriers and the modulation adapted differing according to the required service qualities.

Thus, in response to a service quality required either by a peripheral station or by the base station itself, the transmission management device according to the invention determines the number of carriers and the modulation which it is necessary to allocate to a given information transmission in order to guarantee this service quality.

Correlatively with the sending method, the invention also relates to a device for sending information over a radio communication channel, having means of allocating a number of carriers and a modulation to said information for transmitting it over said radio communication channel, and means of sending said information in the form of carriers modulated by said information, wherein said device has means of reconfiguring the number of carriers and the modulation allocated to the information according to a required service quality, in terms of transmission error rate and transmission rate for a given information transmission, the number of carriers and the modulation reconfigured differing according to the required service qualities.

Correlatively with the reception method, the invention relates to a device for receiving information coming from a radio communication channel, having means of receiving said information sent in the form of carriers modulated by said information and means of selecting the carriers and the modulation allocated to said information, wherein said device has means of reconfiguring the number of carriers and the modulation to be selected as a function of a required service quality, in terms of transmission error rate and transmission rate for a given information transmission, the number of carriers and the modulation reconfigured differing according to the required service qualities.

Another object of the invention is a base station able to communicate information by radio with at least one peripheral station, wherein said base station has a device for managing information transmissions by radio as briefly disclosed above.

According to a particular characteristic, the base station has a sending device and a reception device as briefly disclosed above.

It should be noted that the management device can include the sending device and the reception device mentioned above.

The invention relates to a peripheral station able to communicate information by radio with a so-called base station, wherein said peripheral station has a radio sending device and reception device as briefly described above.

The invention also concerns a network including a base station and at least one peripheral station as disclosed above.

The base station and peripheral stations can have a computer, a printer, a server, a facsimile machine, a scanner, a digital cameral, a digital photographic apparatus, a television, a video recorder or a decoder (known as a “set-top box”).

The invention also relates to a telephone, a photographic apparatus, a printer, a scanner, a camera, a computer, a facsimile machine, a television

receiver and an audio/video player, wherein they have a device as briefly disclosed above.

The invention also relates to :

- an information storage means that is readable by a computer or by a micro-processor holding instructions of a computer program, wherein it permits implementation of the process according to the invention as succinctly presented hereabove ; and

- an information storage means that is removable, partially or wholly, and readable by a computer or a micro-processor holding instructions of a computer program, wherein it permits implementation of the invention as succinctly presented hereabove.

The advantages of this device, network, telephone, photographic apparatus, printer, scanner, camera, computer, facsimile machine, television receiver, audio/video player and storage means being the same as those of the method as briefly disclosed above, they are not repeated here.

The following description and drawings will give a better understanding of the aims and advantages of the invention. Clearly that this description is given by way of example, and has no limitative character. In the drawings:

- Figure 1 depicts the block diagram of a standard system of transmission by multicarrier modulation;

- Figure 2 illustrates symbolically the transmission quality of each subcarrier in an example of transmission by a standard multicarrier system;

- Figure 3 is a block diagram of the device according to the invention, according to a presentation analogous to Figure 1;

- Figure 4 illustrates the transmission quality of each subcarrier in an example of transmission by a system according to the invention, according to a presentation analogous to Figure 2;

- Figure 5 illustrate an example of DS signal generation in the case of digitisation of an analogue source;

- Figure 6 shows an algorithm allocating the data to the different subcarriers;

- Figure 7 shows the block diagram of a multicarrier transmission system including the calculation means necessary for implementing the data allocation algorithm of Figure 6.

- Figure 8 is a block diagram of a transmission system including the invention ;

- Figure 9 is a block diagram of a reception system including the invention ;

- ~~Figure 10~~ Figures 10A and 10B illustrates an exemplary process for inserting the information representative of the type of modulator used ;

- Figure 11 illustrates a form of embodiment of the invention using a computer ;

- Figure 12 shows an algorithm of the transmission process according to the invention, executed by the computer.

- Figure 13 shows an algorithm of the reception process according to the invention

- Figure 14 is a general view of a network according to the invention including a base station SB and several peripheral stations SPi ;

- Figure 15 is a schematic view of a peripheral station SP1 according to a first embodiment of the invention;

- Figure 16 is a schematic view of a base station SB according to a first embodiment of the invention;

- Figure 17 is a detailed schematic view of the sending unit 40 depicted in Figure 15;

- Figure 18 is a detailed schematic view of the carrier modulation circuit 82 depicted in Figure 17;

- Figure 19 is a representation of the binary data 00, 01, 11, 10 in the Fresnel plane;

- Figure 20 is a detailed schematic view of the carrier allocation circuit 84 depicted in Figure 17;

- Figure 21 is a detailed schematic view of the reception unit 72 depicted in Figure 15;

- Figure 22 is a detailed schematic view of the carrier selection circuit 126 depicted in Figure 21;

- Figure 23 is a detailed schematic view of the carrier demodulation circuit 128 depicted in Figure 21;

- Figure 24 is a schematic view depicting the base station SB and peripheral station SP1 according to the invention;

- Figure 25 is an algorithm representing the different steps of the information sending method according to the invention;

- Figure 26 is an algorithm representing the different steps of the information transmission management method according to the invention;

- Figure 27 is an algorithm representing the different steps of the information reception method according to the invention;

- Figure 28 is a schematic view of a peripheral station SP'1 according to a second embodiment of the invention;

- Figure 29 is a schematic view of a base station SB' according to a second embodiment of the invention; and

- Figure 30 is a schematic representation of an OFDM symbol.

In the example below, use will be made of a matrix which can be decomposed according to the Cooley-Tuckey algorithm, which affords an easily understandable presentation of the reasonings.

Prior to the description of the invention, a few matters relating to the conventional method of calculating a discrete Fourier transform, with examples to base 4, will be stated here.

A discrete Fourier transform can be represented by the multiplication of a complex vector U by a matrix, which corresponds well to the obtaining of a series of linear combinations of the components of the initial complex vector.

If W= exp(-j2π/n), with n the number of components of the complex vector of the discrete Fourier transform (DFT), j the root of -1, then the DFT operation can be represented by the equation:

$$\begin{bmatrix} X_0 \\ X_1 \\ X_2 \\ \dots \\ X_{n-1} \end{bmatrix} = \frac{1}{\sqrt{n}} \begin{bmatrix} 1 & 1 & 1 & \dots & 1 \\ 1 & W & W^2 & \dots & W^{n-1} \\ 1 & W^2 & W^4 & \dots & W^{2(n-1)} \\ \dots & \dots & \dots & \dots & \dots \\ 1 & W^{(n-1)} & W^{2(n-1)} & \dots & W^{(n-1)(n-1)} \end{bmatrix} \begin{bmatrix} x_0 \\ x_1 \\ x_2 \\ \dots \\ x_{n-1} \end{bmatrix}.$$

In general terms the so-called nth order Fourier matrix is defined by the matrix:

$$M = 1/\sqrt{n} \begin{bmatrix} 1 & 1 & 1 & \dots & 1 \\ 1 & W & W^2 & \dots & W^{n-1} \\ 1 & W^2 & W^4 & \dots & W^{2(n-1)} \\ \dots & \dots & \dots & \dots & \dots \\ 1 & W^{(n-1)} & W^{2(n-1)} & \dots & W^{(n-1)(n-1)} \end{bmatrix}.$$

The inverse Fourier transform is obtained by replacing W by W'=exp (j2π/n).

If n is a power of 4, this transform can be divided into four groups of four multiplications of a vector by a matrix in accordance with the following form (according to the Cooley-Tuckey algorithm):

$$\sqrt{n}$$

$$\begin{bmatrix} X_{0+k*n/4} \\ X_{1+k*n/4} \\ X_{2+k*n/4} \\ \dots \\ X_{n/4-1+k*n/4} \end{bmatrix} = a_k D_0 T \begin{bmatrix} x_0 \\ x_4 \\ x_8 \\ \dots \\ x_{4(n/4-1)} \end{bmatrix} + b_k D_1 T \begin{bmatrix} x_1 \\ x_5 \\ x_9 \\ \dots \\ x_{n-3} \end{bmatrix} + c_k D_2 T \begin{bmatrix} x_2 \\ x_6 \\ x_{10} \\ \dots \\ x_{n-2} \end{bmatrix} + d_k D_3 T \begin{bmatrix} x_3 \\ x_7 \\ x_{11} \\ \dots \\ x_{n-1} \end{bmatrix}$$

for k=1, 2, 3 ;

with the coefficients a_k, b_k, c_k, d_k equal to the coefficients of the 4th dimension Fourier matrix, that is to say

$$\begin{bmatrix} a_0 & b_0 & c_0 & d_0 \\ a_1 & b_1 & c_1 & d_1 \\ a_2 & b_2 & c_2 & d_2 \\ a_3 & b_3 & c_3 & d_3 \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & -j & -1 & j \\ 1 & -1 & 1 & -1 \\ 1 & j & -1 & -j \end{bmatrix},$$

T is the Fourier matrix of dimension n/4 and D_0, D_1, D_2, D_3 are diagonal matrices consisting of elements W^{il} with $0 \le l \le n/4 - 1$, in accordance with the form:

$$D_i = \begin{bmatrix} W^0 & 0 & \dots & 0 \\ 0 & W^i & \dots & 0 \\ \dots & \dots & \dots & 0 \\ 0 & 0 & 0 & W^{(n/4-1)i} \end{bmatrix},$$ and D_0 being an identity matrix.

Consequently, if the components of a complex vector to be transmitted (associated with the data of a sequence of data representing physical quantities) are taken from an alphabet {1+j, 1-j, -1-j, -1+j}, there are, when complex symbols are transmitted by the so-called OFDM method, no multiplications in the operations to be performed, and only additions or changes of signs, which simplifies the implementation of such a method.

As can be seen in Figure 3, which must be compared with Figure 1 representing a standard multicarrier transmission system, there are found, in a device A according to a first implementation of the invention, a data source 10 and a multicarrier modulator 50 which transmits the data to a radiofrequency interface 60. A demodulator 70 is inserted downstream of the radiofrequency interface 60 in order to process the signal received over the transmission channel, coming from another remote transceiver B (identical to device A), not shown in the figure.

The data source 10 generates a binary data stream which constitutes the signal to be transmitted.

In a conventional device not according to the invention, this stream of the "serial" type is converted into a "parallel" stream by the serial-to-parallel converter 20, so as to reduce the transmission rate of the modulating signals. This parallel stream is then sent to the multicarrier modulator 50, which effects the modulation necessary for the transmission over the chosen transmission channel.

In the example presented, the serial stream is transformed into a parallel stream in eight bits. In this case, if the transmission rate of the binary source is D, the rate of each stream at the output of the serial to parallel converter 20 will therefore be D/8.

Each of these stream then modulates a subcarrier by virtue of the modulators 30, 31 ..., 37 (eight subcarriers in this example); the modulation can be of different types: phase, amplitude or frequency modulation, according to conventional techniques which are not part of the object of the invention.

An adder 40 next adds all the modulated subcarriers so as to obtain the global signal S(t), which is then transmitted to the "radiofrequency" interface (also denoted RF) 60.

It is significant to note that the binary data X_0, X_1, X_2, ... X_7, issuing from the converter 20 and used for modulating the subcarriers, can consist of several bits. They will then more generally be referred to as "symbols". In this case the modulations employed can be complex (for example according to types known to persons skilled in the art as QPSK, 8PSK, 16QAM, 64QAM etc) in order to improve the spectral efficiency.

These elements constitute a conventional multicarrier device, known to persons skilled in the art. It will therefore not be detailed any further in the present description.

On the other hand, the device according to the invention also has two parts which do not exist in conventional devices: namely on the one hand a premodulator part 100, inserted upstream of the conventional multicarrier modulator 50 (replacing the serial to parallel converter 20) and on the other

hand a post-demodulator part 200, inserted downstream of the multicarrier demodulator 70.

In summary, the premodulator part 100 presents the different inputs of the modulator 50 (one input corresponding to each subcarrier 30, 31 etc), the different data to be transmitted according to their significance and the transmission quality level of each subcarrier.

This premodulator 100 also inserts in the data a signal 240 representing the transmission quality observed on each subcarrier in the so-called "return" direction, also denoted B → A.

This premodulator 100 also inserts in the data a signal 135 representing the order of these said data in the serial stream, in the direction A → B.

The post-demodulator part 200 effects on the one hand the analysis of the channel so as to supply the signal 240 representing the quality of the transmission of each subcarrier 30, 31 ... in the so-called "return" direction, and on the other hand extracts a signal 230 representing the transmission quality observed by a remote receiving device on each subcarrier in the so-called "outward" direction, also denoted A → B, this signal 230 being inserted by the premodulator 100 of the remote device situated at the other end of the channel, so as to control the local premodulator module 100.

This post-demodulator 200 also extracts a "DP" signal 235 representing the order in which there were arranged the different data to be transmitted at the input of the premodulator of the remote transmitter.

More precisely, the premodulator part 100, inserted upstream of the multicarrier modulator 50, consists of a data allocation unit 130, a data insertion control unit 115, a data classification unit 110 and a frequency allocation unit 120.

The post-demodulator part 200 inserted downstream of the demodulator 70 consists of a channel analysis unit 220, an "FCD extractor" frequency classification signal extraction unit 210, a "DP extractor" unit 215 for extracting the signal representing the order of the data in the serial stream

presented to the remote premodulator, and a data serialisation unit 205 (also referred to as a serialiser).

The electronic design detail of these parts results from the transmission method as disclosed here.

The channel analysis unit 220 analyses the transmission channel, for example by evaluating different characteristics of known pilot signals inserted by the remote device B (situated at the other end of the transmission channel). There are several analysis techniques (pilot signals at fixed frequencies, at frequencies sliding in time, etc) known to persons skilled in the art.

The result of this analysis constitutes the signal 240 (so-called FCD or "frequency classification data" signals). This is supplied to the control data insertion unit 115, which inserts it in the data stream to be transmitted, so as to inform the remote device B of the behaviour of this transmission channel. This FCD signal 240 therefore represents the characteristics of the channel in the B → A direction, as observed by the local device A.

The FCD signal extraction unit 210 extracts, from the data received and demodulated by the demodulator 70, an FCD signal 230, a signal generated and inserted by the channel analysis part 220 and control data insertion part 115 of the remote device B. This FCD signal 230 represents the characteristics of the channel in the direction A → B, as observed by the remote device B.

The "DP extractor" signal extraction unit 215 extracts, from the data received and demodulated by the demodulator 70, a signal 235, a signal generated and inserted by the frequency allocation unit 120 and control data insertion unit 115 of the remote device B. This signal 235 represents the order of the data in the serial stream presented to the premodulator 100 of the remote device B. This signal 235 will be used by the serialisation unit 205 so as to transform the parallel stream of the received data into a serial stream identical to that presented to the premodulator of the remote device B.

The classification unit 110 for data to be transmitted generates a DS (data significance) signal 111 representing the significance of each data item supplied by the source. An example of generating a DS signal is given in Figure 5.

The frequency allocation unit 120 decides on the distribution of the data over the different subcarriers from the DS signal 111 and FCD signal 230 (in the direction A → B), and optionally other parameters supplied by the user, and generates accordingly a data allocation command (DAC) signal 125.

The frequency allocation unit 120 also supplies a signal 135 (data position) representing the order which the data allocated to the different subcarriers had relative to each other in the serial stream presented to the premodulator 100. The signal 135 is used by the control data insertion unit 115, which inserts it in the data to be transmitted so as to enable the serialisation unit 205 of the remote device B to correctly reclassify these data after transmission.

Different data-frequency allocation algorithms can be used. An example of a simple algorithm is given non-limitatively in Figure 6.

The data allocation command signal 125 is sent to the data allocation unit 130, which then switches each data item supplied by the source 10 to the subcarrier (the input of the modulator 50) chosen by the frequency allocation unit 120.

For a correct functioning of the invention, the data supplied to the data allocation unit 130, to the control data insertion unit 115 and to the frequency allocation unit 120 must be correctly phased; which is effected using devices well known to persons skilled in the art (for example a delay line for delaying the signal which is in advance). The complex signal coming from the modulator 50 is then transmitted to the RF unit 60 for sending via the channel to the remote device B.

Figure 4 then illustrates an example of the distribution of the symbols to be transmitted over the different subcarriers for two different times $t = t_1$ and $t = t_2$, in the case of a multicarrier transmission device according to the invention.

The index of the data (0 to 7) corresponds to the order generated by the source 10. The variations in characteristics of the channel are symbolised by the variation in size of the arrows representing the subcarriers (signal to noise ratio, which amounts for example to observing the attenuation of the channel at the frequency under consideration).

Assuming that the data are not of equal significance, and for example that the data with the highest index are the most significant, it can be seen that the significant data will be correctly transmitted at any time whatever the variations in the channel.

Figure 5 then illustrates an example of generation of a DS (data significance) signal 111 by the unit for classifying data to be transmitted 110.

In this particular case, the source 10 used comprises an analogue source 11, digitised before transmission. An analogue to digital converter unit 12 (ADC) for this purpose generates a continuous sequence of bits, each block of eight bits representing an analogue value to be transmitted. By synchronising the analogue to digital converter 12 and the data classification unit 110, it is possible to generate simply a DS signal 111 which will take a different value for each bit.

For example, if, in a set of bits D0, ... D7 supplied by the converter 12, the first bit D7 is the most significant, it suffices to cause to correspond to it a signal of maximum significance (that is to say index 7 here). The index 6 is then made to correspond to the following bit D6, the index 5 to the bit D5 etc. This can be achieved easily by using a 3-bit counter performing the data classification function. This counter will be incremented by the serial clock of the converter and initialised to 0 at each new analogue data item.

Figure 6 gives an example of an algorithm allocating the data to the different subcarriers according to the level of interference measured on each subcarrier and the significance of the data. This algorithm is intended to be implemented by the frequency allocation unit 120.

During the initialisation step 310, the device reads the information contained in the FCD signal 230 and DS signal 111 and stores them.

The first step 320 next consists of classifying the subcarriers in order of decreasing interference and storing in memory the table thus obtained.

The following step 330 consists of classifying the indices of the data to be transmitted in order of increasing importance, using the information contained in the DS signal 111. The result of this classification is also stored in memory.

The following step 340 consists of transmitting the data allocation command signal 125 to the data allocation unit 130, this DAC signal 125 being in fact composed of pairs (subcarriers, index of the data).

After the outputting of each pair, a test 350 is performed in order to check whether all the pairs have been supplied (there are as many pairs as there are subcarriers). If the test is negative, the following pair is supplied; if the test is positive, step 360 is passed to.

The following step 360 consists of transmitting the data position signal 135, representing the order which the data allocated to the different subcarriers had relative to each other in the serial stream presented to the premodulator, to the control data insertion unit 115, which inserts it in the data to be transmitted.

Next, the initialisation step 310 is returned to in order to prepare to supply the next allocation table (DAC signal 125).

It should be noted that the FCD signal 230 can be updated at a slower rate than that of the data to be transmitted. In this case, step 320 does not have to be performed for each new data item, but only when the FCD signal 230 is refreshed.

In a preferred embodiment, when the data always have the same relative significance level (analogue to digital conversion, for example), the data position signal can be omitted, the knowledge of the frequency classification order then being sufficient to reclassify the data on reception.

Figure 7 describes a means of embodying the invention including a CPU calculation unit 400, a temporary data storage unit 410, a program

storage unit 420, character entry means (a keyboard for example) 430, image reproduction means 440 and means allowing inputs and outputs 450.

The algorithm described above can easily be integrated into this embodiment by a person skilled in the art, but other means of implementation are possible.

In a variant using a transmission by coaxial cable, the channel is "fixed", in that its quality does not vary over time, and it is therefore not necessary to make an estimation of the channel, but classification of the data can nevertheless make it possible to use the high frequencies which are most attenuated on this type of channel, then sending the data of less significance thereon.

It should be noted that the data source 10 can for example be an image compression system using progressive coding techniques such as coding in sub-bands, by fractals, by transform (discrete cosine transformation: DCT, wavelets), in video object (MPEG4); these systems naturally produce signals of variable significance, the data classification unit 110 can be reduced to a coding of this significance level.

Moreover, in an application of the invention with a view to another objective, it can be chosen to favour a saving in energy by using only the carriers with a very low noise level and therefore by transmitting at low power, even if it means reducing the transmission rate (since there are fewer subcarriers used simultaneously) and therefore taking a little longer to transmit the message. The transmission principle for all that remains substantially similar.

In the following description of a second aspect of the invention, detailed descriptions of the devices for reducing the peak-to-mean ratio, as well as of the conventional OFDM modulation devices, have been deliberately omitted.

By way of illustration, the preferred form of embodiment will be described in the case of a transmission of data representing an image and

compressed with the so-called « sub-band » method, using algorithms for reducing the peaks by modifying the matrix of the FFT or by adding redundancy bits (as described in this case in patent document US 5 636 247).

As a brief reminder, the method of compressing data by encoding in sub-bands enables the image for transmission to be divided into a number of hierarchically arranged blocks of data (referred to as 'sub-bands'), this being effected iteratively.

Upon the first iteration, four sub-bands of data are created : the first contains the low frequencies of the image, the second the horizontal high frequencies, the third the vertical high frequencies, and the fourth the diagonal high frequencies.

Each sub-band comprises four times less data than the original image.

Upon the second iteration, the first block is, itself, broken down into four new blocks containing the low frequencies, the horizontal high frequencies, the vertical high frequencies and the diagonal high frequencies relating to this block.

As the total number of data elements is constant at each iteration, one can proceed in this way until the expected result is obtained (insofar as there remain enough points to perform the operations).

This breaking down process (without losses) is followed by a quantization step (with losses) wherein the data present in each block is encoded with a quantization level that depends on the reference of the block and the desired compression rate.

Given the sensitivity of the human eye, which is more receptive to the low frequencies than to the high frequencies, it will be readily appreciated that the invention is perfectly applicable to the transmission of images compressed using this algorithm. Indeed, it directly supplies the information representative of the importance of each data element or block of data elements (deduced from the reference of the block to which it belongs).

The peak reducing algorithms chosen to illustrate this description of the invention are as follows :

1/ Reduction of the peak-to-mean ratio favoring the data rate : this algorithm consists in changing the coefficients of the Fourier matrix as a function of the input vector (set of data for transmission) in such a way that the output signal (called the OFDM symbol) has a peak-to-mean ratio as close as possible to 1.

Changing the coefficients of the matrix has the drawback of increasing sensitivity to noise, hence of causing the bit error rate to deteriorate slightly.

2/ Reduction of the peak-to-mean ratio favoring the bit error rate : this algorithm, which is described in US patent 5.636.247, consists in adding to the input vector supplementary data calculated in such a way that the output signal (called the OFDM symbol) has a peak-to-mean ratio as close as possible to 1.

This method, which in no way affects the modulation process, has the advantage of not causing the bit error rate of the transmission to deteriorate, but it reduces the efficiency of the transmission since it reduces its data rate.

Figure 8 is a diagram showing an OFDM type transmitter designed according to the invention.

A transmitter according to the invention comprises :

- an OFDM modulator implementing a means for reducing the peak-to-mean ratio favoring a maximum data rate ;
- an OFDM modulator implementing a means for reducing the peak-to-mean ratio favoring a bit error rate ;
- a means for attributing a criterion of importance to the data for transmission if the latter is not classified by the source ;
- a means for inserting data into a stream of data ; and
- a radiofrequency interface.

More precisely, a data source, 10, supplies a block of data for transmission to an insertion unit, 1020, responsible for inserting an item of information representative of the type of OFDM modulator chosen (from two OFDM modulators, 1040, 1050, favoring either the minimum bit error rate or the maximum data rate).

Data source 10 also provides a command signal, 1015, the function of which is, on one hand, to indicate to the said insertion unit 1020 what item of information is to be inserted (according to a classification of the data in terms of importance), and, on the other hand, to control multiplexers 1030 and 1060 so as to use chosen OFDM modulator 1040, 1050.

The modulated signal is then transmitted to a radiofrequency interface, 1070, of a conventional type.

OFDM modulators 1040 and 1050 are, respectively, a first OFDM modulator 40 adapted to implement a process for reducing the peak-to-mean ratio favoring the minimum bit error rate (BER), and a second OFDM modulator 50 adapted to implement a process for reducing the peak-to-mean ratio favoring the data rate.

In the same way, figure 9 is a diagram of an OFDM type receiver implementing the invention.

A receiver according to the invention uses a demodulator adapted to take into account the system for reducing the peak-to-mean ratio favoring the data rate, a demodulator adapted to take into account the system for reducing the peak-to-mean ratio favoring the minimum bit error rate, and a means for extracting control data from the data received.

More precisely, the signal received by a radiofrequency interface, 1110, is sent simultaneously to a unit for selecting a demodulator, 1120, and to the input to a multiplexer, 1130.

Extraction unit 1120 extracts from the data received an item of information representative of the type of modulator chosen and deduces therefrom the state of demultiplexers 1130 and 1160 (selection blocks of the demodulator) which it positions via a signal, 1125.

OFDM demodulation blocks 1140 and 1150 correspond, respectively to an OFDM demodulator 1140 adapted to implement a process for reducing the peak-to-mean ratio favoring the minimum bit error rate (BER) and an OFDM demodulator 1150 adapted to implement a process for reducing the peak-to-mean ratio favoring the data rate.

The item of information representative of the type of OFDM modulator chosen can take only a very limited number of states (two in the present non-limitative example). It is then clear that it can easily be transported on the control signals that are necessarily attached to the data for transmission.

In the example described here, advantage is taken of the synchronization data P, S of the OFDM symbols to transport it. Technical literature describes a host of proposals regarding synchronization.

In general, a known prefix P and a known suffix S are added to an OFDM symbol, on which a correlation is effected in a conventional type of correlator (not shown in the figures), or a cyclic prefix is used, i.e. the information contained in one part of the message is repeated after a precise time interval.

A delay line enables the delayed signal to be correlated with the incoming signal and a series of correlation peaks are obtained that enable a synchronization signal to be restored.

In the case of such a synchronization process, to transport an item of binary information, it suffices to change the sign of the data in prefix P (or in suffix S) in order to obtain an opposite line signal at the correlator output.

This signal is then the carrier of the synchronization information (through its frequency) and of the information on the type of modulation (through its sign).

Figure 10 illustrates such an example of insertion of the item of information representative of the type of modulator chosen in synchronization sequences (in the case of the preferred method described above).

Figure 10A represent the signals transmitted in the event of the first OFDM modulator, 1040 (favoring the minimum bit error rate), being

chosen. In this case, the data sequences are transmitted in packets (each one corresponding to an OFDM symbol) each comprising a prefix P and a suffix S, forming a synchronization sequence. The data packets are separated by a silence (corresponding to a guard time) at the time of transmission.

The data inserted into prefixes P and suffixes S is chosen in such a way as to generate a positive signal at the correlator output.

Figure 10B represent the signals transmitted in the event of the second OFDM modulator, 1050 (favoring the maximum data rate), being chosen. In this case, the data inserted into prefixes P and suffixes S is chosen in such a way a to generate a negative signal at the correlator output (replacement of the P sequence by the opposite sequence). In this way, a means of identifying the choice of OFDM modulator is easily obtained.

Figure 11 illustrates a means of producing the transmitter according to the invention including a CPU (Central Processing Unit) computing unit, 400, a unit, 410, for temporarily storing the data, a program storage unit, 420, character acquisition means (keyboard), 430, image restoring means, 440 (screen), and means permitting inputs / outputs, 450.

The read-write, or Random Access Memory, 410 serves as a relay for the data for transmission or reception. It will also be noted that the vectors resulting from the modulation and demodulation operations are also resident the Random Access Memory, as is the received data placed in the form of vectors prior to (« data-in ») and after (« data-out ») their transformation by the Fourier transform.

Figure 12 shows an algorithm implementing the invention in an OFDM transmitter. When a new succession of data is ready for transmission (step 1200), the importance information (signal 1015) that is associated therewith is extracted (step 1210) and analyzed (step 1220).

If the data element is considered to be highly significant, the « Most Significant Data » item of information is inserted (step 1230) and the algorithm is applied that generates an OFDM signal after the addition of

redundancy bits that reduce the peak value of the signal (step 1240) (favoring the minimum bit error rate).

If the data is considered to be less significant, the « Least Significant Data » item of information is inserted (step 1250) and the algorithm is applied that generates an OFDM symbol using an inverse fast Fourier transform matrix modified so as to reduce the peak value of the signal (step 1260) (favoring the maximum data rate).

Once the OFDM symbol has been generated, it is transmitted conventionally via the RF interface (step 1270).

To summarize, the mode of operation for transmission is as follows : when the transmitter receives a block of data for transmission, it analyzes its importance (either by reading the item of information added by the source or by identifying the source, or by any other means) and decides on the type of OFDM modulator to use.

If the data is classified as of prime importance (in our example, low frequency image), the system chooses the first OFDM modulator, 1040, ensuring the minimum bit error rate.

If the data is classified as of lesser importance (in our example, high frequency images), the system chooses the second OFDM modulator, 1050, ensuring the maximum data rate.

In both cases, after making this choice, the system inserts an item of information via block 1020 to indicate to the receiver what type of OFDM modulator 1140, 1150 to use (one example of a module for inserting this item of information is described below) and controls multiplexers 1030, 1060 in such a way that the data undergoes the chosen modulation.

In reception (figure 13), when the receiver receives a data block via its RF interface 1110 (in step 1300), it first of all extracts therefrom, in extraction unit 1120 (in step 1310), the item of information representative of the type of modulator used, analyzes it (in step 1320) and generates a command signal, 1125, (in step 1330) representative of the type of modulation to be applied. The demodulator selection blocks 1130, 1160 are thus positioned in

such a way that the data received undergoes the appropriate demodulation (in steps 1340, 1350). The demodulated information is finally transmitted to its destination (in step 1360).

It should be noted that, to simplify presentation, 2 separate modulators (and 2 separate demodulators) are shown here ; however, in practice, it is more advisable to use the common parts (IFFT, parallel / series conversions, FFT, etc.) once only and to switch the parts specific to each peak-to-mean ratio reduction process.

All the steps described above can be implemented using software or hardware means.

The choice of one or the other is made on the basis of considerations connected with the bit rate to be obtained. Execution by a software means has been more explicitly described with reference to figure 12. Although the invention has been described in the simple case of using two processes for reducing the peak-to-mean ratio, it is obvious that the present invention can extend to the use of any number n of types of processing by using higher levels of data classification and a more complex system for encoding the information representative of the « type of modulator ».

In another embodiment, it is possible for the series of instructions forming the program not to be resident in a ROM but placed in a RAM, and then executed. The above described algorithm can easily be integrated in this embodiment by a man of the art, but other forms of embodiment can be contemplated.

It should be noted that data source 10 can, for example, be an image compression system using progressive encoding techniques such as encoding in sub-bands, with fractals, or with a discrete cosine transform (DCT, wavelets, video object (MPEG4) ; as these systems naturally produce signals of varying importance, the data classification unit can simply amount to an encoding of this level of importance.

As depicted in Figure 14 and designated by the general reference denoted 2010, a network according to the invention consists of a so-called base station SB and several peripheral stations SP_i, with i = 1 to N.

These peripheral stations SP_i are distant from the base station SB, each connected to it by radio link and able to move with respect to it.

The base station SB communicates with the peripheral station SP_1 by means of the incoming radio link 2012 and the outgoing radio link 2014, with the peripheral station SP_2 by means of the incoming radio link 2016 and the outgoing radio link 2018 and with the peripheral station SP_n by means of the incoming radio link 1N and the outgoing radio link 2N.

The transmissions 2012, 2014, 2016, 2018, ..., 1N and 2N are effected by means of radio interfaces installed in each station and communication channels allocated to these transmissions.

The block diagram of Figure 15 depicts a more detailed view of a first embodiment of a peripheral station, for example of the station SP_1, which comprises a data source 2020 and a device 2022.

In general terms, the device 2022 is a device for sending and receiving information according to the invention.

This information is intended to be transmitted over a radio communication channel, in the form of carriers modulated by said information.

The data source 2020 is for example a digital camera, a computer, a printer, a server, a facsimile machine, a scanner, a digital camera, a digital photographic apparatus, a television, a video recorder or a decoder.

This sending and reception device 2022 includes a data processing unit 2024 comprising a calculation unit 2026 denoted CU, a temporary data storage means 2028 (RAM), a permanent storage means 2030 (ROM), a bus interface 2032 and a bus 2034 which connects the data source 2020 to said interface.

The sending and reception device 2022 comprises a bus 2036 serving the calculation unit 2026, the storage means 2028 and 2030 and a modem interface 2038.

The sending and reception device 2022 also has an information sending unit 2040 and an information reception unit 2042, as well as a radio module 2044 to which said units 2040 and 2042 are connected.

The radio module 2044 is equipped with a radio antenna 2046. The radio module and the antenna constitute on the one hand, with the sending unit 2040, sending means and on the other hand, with the reception unit 2042, information reception means.

For its part, the base station SB comprises, as depicted in Figure 16, a data source 2050 and an information sending and receiving device 2052 according to a first embodiment of the invention.

This information sending and receiving device 2052 includes a data processing unit 2054 comprising a calculation unit 2056 denoted CU, a temporary data storage means 2058 (RAM), a permanent storage means 2060 (ROM), a bus interface 2062 and a bus 2064 which connects the data source 2050 with said interface.

The sending/reception device 2052 also includes a bus 2066 serving the calculation unit 2056, the storage means 2058 and 2060 and a modem interface 2068.

The sending/reception device 2052 also includes an information sending unit 2070 and an information reception unit 2072, as well as a radio module 2076 to which the said units 2070 and 2072 are connected. The radio module and the antenna constitute on the one hand, with the sending unit 2070, sending means and on the other hand, with the reception unit 2072, information reception means.

The data source 2050 is for example a digital camera, a computer, a printer, a server, a facsimile machine, a scanner, a digital camera or a digital photographic apparatus, a television, a video recorder or a decoder.

The sending 2070 and reception 2072 units are identical respectively to the sending unit 2040 and to the reception unit 2042 of the peripheral station SP_1 of Figure 15.

A description will now be given in more detail of the sending 2040 and reception 2072 units with reference to Figures 17 to 23.

The information sending unit 2040 depicted in Figure 17 includes a encoder 2080 and a means of allocating to said information a number of carriers and a modulation. These means of allocating carriers and a modulation consist partly of a carrier modulation circuit 2082 and partly of a carrier allocation circuit 2084.

This sending unit 2040 also has means 2086 of reconfiguring the number of carriers and the modulation allocated to the information to be transmitted.

These means 2086 consist partly of a circuit 88 for reconfiguring the number of carriers and partly of a circuit 2090 for reconfiguring the modulation. The implementation of and conditions for the reconfiguration are explained below.

The sending unit 2040 also includes a circuit producing an inverse fast Fourier transform (IFFT) 2092 and a frequency multiplexer (MUX) 2094.

When the sending unit 2040 is in operation, a set of successive information items J, coming from the data source 2020, is stored in the RAM 2028 (Fig 15).

This information can be processed in the unit CU 2026, and can for example undergo an operation of compression or of addition of a cyclic redundancy code.

The information in the RAM 2028 which has possibly been processed is first of all distributed in sequences S of data, for example of the binary type.

Each sequence S is sent to the modem interface 2038, and then to the sending unit 2040 where the binary data streams, depicted by the reference 2102 in Figure 17, are first of all coded in the circuit 2080 and represented by the reference 2104, and then are injected into the carrier modulation circuit 2082, also referred to as the mapping circuit.

In this circuit, the data streams 2104 are then grouped in R bits according to the modulation chosen, and then transformed into complex numbers, according to a coding alphabet also stored.

The set of n complex numbers form a complex vector U marked by the reference denoted 2106 in Figure 17 and which is then delivered to the circuit 2084.

In the example described here, R is for example equal to two.

As depicted in Figure 18, the modulation circuit 2082 includes, more particularly, a unit 2098 for the serial to parallel conversion of the incoming data sequences.

This unit delivers at its output blocks of bits intended for a matching unit denoted 2100. The matching unit 2100 has tables containing stored complex numbers and matches a block of R bits with a given complex number according to the modulation chosen.

The complex vectors U issuing from the circuit 2082 are for example depicted in the Fresnel plane in coordinates I and Q, as indicated in Figure 19, according to a mapping of the QPSK type (quaternary phase shift keying).

The pairs of binary data 00, 01, 11 and 10 depicted in Figure 19 are respectively associated with the complex numbers 1+j, -1+j, -1-j, 1-j which bear the name QAM symbols (quadrature amplitude modulation) and which are represented by the reference 2106 in Figure 17.

It should be noted that the modulation applied in the circuit 2082 can take different forms: BPSK (binary phase shift keying), QPSK, 8PSK, 16QAM, 32QAM, 64QAM... according to the choice applied.

In general terms, the size and number n of complex numbers issuing from the circuit 2082 depend on the modulation (type of modulation and level) and on the number of carriers allocated. Such an allocation will be described in more detail below.

Returning to the example described with reference to Figure 17, during a transmission, the complex numbers forming a complex vector 2106 are

transferred into the carrier allocation circuit 2084, which is depicted in more detail in Figure 20.

Thus, in this figure, the carrier allocation circuit 2084 in some way fulfils the role of a switch and matches a complex number with an selected input of the circuit 2092 which effects an inverse fast Fourier transform (IFFT).

Different complex numbers are therefore allocated to given inputs e_i, $i = 0, .., n$ of the circuit 2092 as a function of information on the number of carriers selected for the transmission of information and the numbers of the inputs of the circuit 2092 corresponding to the selected carriers, information which is determined elsewhere, as will be seen subsequently.

In this way there is obtained, at the input of the (IFFT) circuit 2092, a complex vector V in which each component represented by the reference 2108 in Figure 17 corresponds to a selected carrier, modulated by complex number.

This circuit performs the multiplication of each complex vector V by the Fourier matrix M mentioned at the start of the disclosure in order to obtain the transformed vector Y.

This transformed vector Y consists of n complex numbers represented by the reference 2110 in Figure 17.

The complex numbers 2110 generated at the output of the (IFFT) circuit 2092 are then multiplexed by the (MUX) circuit 2094 in order to create a signal 2112 comprising all the multiplexed carriers, each carrier transporting the data contained in a number of the group of complex numbers 2106. The signal 2112 thus forms what is referred to as an OFDM symbol.

This signal is then modulated by a radio carrier at a modulator, not shown, included in the radio module 2044 of Figure 15, for it to be transmitted in a transposed band over the radio communication channel in question.

A description will now be given in more detail of the reception unit 2072 of the base station SB with reference to Figures 21 to 23.

The reception unit 2072 includes a frequency demultiplexer (DEMUX) 2122, a circuit effecting a fast Fourier transform (FFT) 2124, means of selecting the carriers and the modulation allocated to the information

transmitted over the radio communication channel. These selection means consist partly of a carrier selection circuit 2126 and partly of a carrier demodulation circuit 2128 (Figure 21).

The reception unit 2072 also includes means of reconfiguring the number of carriers and the modulation to be selected.

These reconfiguration means consist partly of a circuit 2130 for reconfiguring the number of carriers to be selected and partly of a circuit 2132 for reconfiguring the modulation to be selected. The implementation and the reconfiguration conditions are explained later.

The reception unit 2072 also includes a decoder 2134 for the coded data and means 2136 for measuring the transmission error rate on the radio communication channel in question.

The reconfiguration means 2130, 2132 and the measuring means 2136 form a unit 2138 referred to as the receiver control unit.

When the reception unit 2072 is in operation, the radio signal is received from the radio communication channel by the antenna 2046 and is for example filtered in the radio module 2044 of Figure 15.

The filtered signal undergoes automatic gain control thus returning the amplitude of said signal to a predetermined level, which is acceptable for the reception unit 2072 to be able to function.

The signal is thus amplified because of the high attenuations which it can undergo when it is transmitted over the communication channel.

The power of the amplified signal is then measured and compared with a reference power. If the amplified and measured power does not correspond to this reference power, the gain of the amplifier is adjusted by circuits which are not shown but which are known to persons skilled in the art.

The signal is demodulated in the radio module 2044 by the radio carrier used during the modulation on sending of the signal.

The signal represented by the reference 2140 in Figure 21 is then transmitted to the reception unit 2072, demultiplexed at the demultiplexer (DEMUX) 2122, in order to obtain a group of samples 2142 of the signal

containing the group of carriers modulated by the complex numbers and forming a complex column vector Y'.

A fast Fourier transform (FFT) is then applied by the (FFT) circuit 2124 to the samples 2142 in order to obtain the signals 2144 containing the carriers modulated by the symbols. The calculation of the direct fast Fourier transform consists of multiplying the matrix M', the inverse of the matrix M mentioned above, by the vector Y' in order to obtain a vector consisting of n complex numbers each modulating a carrier.

It should be noted that the matrices M and M' satisfy the equation MM' = Id, where Id designates the identity matrix.

When the matrix M corresponds to an inverse Fourier transform, the matrix M' corresponds to a direct Fourier transform, but it should however be remarked that the order of the matrices can be reversed.

According to a variant, not shown, the matrices M and M' satisfying the equation MM' = Id are Hadamard matrices.

The different outputs of the (FFT) circuit 2124 are connected to different inputs of the carrier selection circuit 2126 (Figure 22). This circuit 2126 selects, from amongst the different outputs of the (FFT) circuit 2124, the carriers which have been used for transmitting complex numbers or new carriers more adapted to the relevant information transmission and supplies, at its output, said complex numbers 2146 in parallel. These complex numbers form the approximate complex vector Z.

The selection circuit 2126 fulfils as it were the role of a switch.

Each of the n complex numbers corresponds to a point in the Fresnel plane which is depicted in Figure 19.

The signals 2146 consisting of complex numbers are then supplied to the demodulation circuit 2128 in order to generate the coded digital data sequence 2148.

As depicted in Figure 23, the demodulation circuit 2128 includes more particularly a matching unit 2150 which comprises tables containing

binary data groups and blocks of bits with a block size corresponding to the chosen modulation (type and level).

Thus this unit 2150 receives, at its input, complex numbers 2146, for example 1+j, -1+j, -1-j, 1-j, and matches with them respectively the pairs of binary data 00, 01, 11 and 10 (Figure 19) since the QPSK modulation was chosen, as seen above, at the time of sending.

In order to obtain this matching, provision is made for performing a decision step on the position in the Fresnel plane on the points of said complex approximate vector Z with respect to the points of the coding alphabet used at the time of sending, and which are those forming the complex vector U, associated with the information which may have been sent.

The decision step is performed according to a criterion which takes into account the minimum value of the Euclidean distance between each point obtained for the approximate vector Z and those corresponding to the vector U.

When the Euclidean distance calculated between one of the points obtained for the approximate vector Z and one of the points of the alphabet is minimal, it is deduced therefrom that the point which may have been sent is that of the alphabet.

The decision step can also be performed in accordance with a decision at the maximum likelihood on a set of symbols, using a Hamming distance or a Euclidean distance and a Viterbi algorithm.

Thus the complex numbers are each associated with a point of the coding alphabet used on sending and supplying the binary data sequences which have been transmitted.

The reconfiguration means 2132 can modify the modulation applied, as will be seen subsequently.

The pairs of binary data marked by the reference 2152 in Figure 23 are sent in parallel to a unit 2154, which performs the parallel to serial conversion of said data and delivers the data 2148 to the decoder 2134.

The reconfiguration means 2132 also act on the conversion unit 2154, supplying to it the above-mentioned number R in accordance with which the binary data are grouped.

The sequences S of data issuing from the decoder 2134 of Figure 21 are then stored in the RAM 2028 in Figure 15 and processed by the processing unit CU 2026.

It should be noted that the transmission of carriers modulated by symbols, which has been described here, concerns a transmission of symbols by a modulation technique known as OFDM.

However, other types of transmission of carriers modulated by symbols can also be suitable, such as, for example, a radio transmission technique known as FDMA (frequency division multiple access) or a spectrum spreading technique by frequency jumping.

Figure 24 depicts the peripheral station SP_1 and the base station SB communicating information which each other by means of the incoming link 2012 and the outgoing link 2014.

The peripheral station SP_1 is in all respect identical to the one shown in Figure 15. The base station SB repeats all the elements indicated in Figure 16, but their arrangement has been somewhat modified in order to show new elements.

The reference 2052 of the information sending and reception device has disappeared in order to show the reference 2170, which corresponds to a device for managing information transmissions by radio between the base station and the peripheral station SP_1 according to the invention.

This transmission management device 2170 includes the sending and reception device 2052 of Figures 16, but this has not been reproduced in order not to complicate the diagram.

This transmission management device 2170 has, as depicted in Figure 24, inserted between the sending 2070 and reception 2072 units, a transmission management unit denoted 2172.

When the peripheral station SP_1 wishes to communicate information to be base station SB over the relevant radio channel, it first sends a request specifying a required service quality for the information transmission to come.

This required service quality specifies the transmission error rate and transmission rate required for the information transmission in question between the base station and the peripheral station.

The transmission management device 2170 includes, on the one hand, means of receiving this request which consist of the antenna 2078, the radio module 2076 and the reception unit 2072 and on the other hand a management unit 2172.

This transmission management device 2170 also has means of receiving at least one measurement of the transmission error rate for a given information transmission, a measurement which was made by the means denoted 2136 in Figure 21.

The management unit 2172 has means, denoted 2174, of determining a number of carriers and a modulation adapted in response to the required service quality, in terms of transmission error rate and transmission rate, for a given information transmission.

It should be noted that this number of carriers and this modulation vary according to different service qualities required on one and the same radio communication channel and for different information transmissions.

These determination means 2174 communicate bidirectionally, as depicted in Figure 24 by two arrows, with the reception unit 2072.

The means 2174 determine the number of carriers and the modulation adapted to a service quality request, with a view to their allocation to the radio communication channel allocated to the relevant information transmission.

These determination means 2174 communicate with the sending unit 2070 in order to transmit to the peripheral station SP_1 the transmission parameters which are the number of carriers and the modulation.

These transmission parameters are also transmitted to the reception unit 2072 of the base station SB.

The management unit 2172 also has means 2176 one the one hand for analysing the measurement of the transmission error rate received by the measuring means 2136 of the reception unit 2172 and transmitted to said unit 2176 and on the other hand for comparing the result of this analysis with the required service quality, in terms of transmission rate and transmission error rate required.

The result of this comparison is transmitted to the determination means 2174.

It should be noted that the means 2174 of determining the number of carriers and the modulation adapted to an information transmission are used before the relevant information transmission occurs.

However, as will be seen subsequently, these determination means can also be used during the information transmission itself.

More particularly, the service quality required for a given information transmission is expressed in terms of transmission error rate threshold and variation in transmission rate acceptable for said information transmission.

Thus, for an information transmission, which is similar to the transmission of files, the transmission rate may vary to a great extent whilst the acceptable error rate should be as low as possible and should not vary.

On the other hand, for applications of the real-time type, the transmission rate must be as constant as possible whilst the error rate, for its part, can vary.

The invention makes provision for adapting, to each required service quality which, as has just been seen, can be very different from one information transmission to another, a given pair consisting of a number of carriers and a modulation.

A description will now be given of the sending, transmission management and reception methods according to the invention, with reference to the respective algorithms in Figures 25 to 27.

As depicted in Figure 25, the sending method according to the invention includes a step denoted E_1 during which the peripheral station SP_1 transmits to the base station SB a transmission request with which a required service quality is associated.

This service quality specifies the transmission rate and the transmission error rate acceptable for the given information transmission between the peripheral station SP_1 and the base station SB.

As has just been seen, the service quality also specifies the transmission error rate threshold and the variation in the transmission rate acceptable for the information transmission in question.

As depicted in Figure 26, the method of managing radio transmissions between the peripheral station SP_1 and the base station SB, according to the invention, includes a step denoted G_1 during which the transmission management device 2170 of the base station SB receives from the peripheral station SP_1 the transmission request and the associated service quality request.

The transmission management device 2170 determines, by virtue of the means 2174, the transmission parameters (number of carriers and modulation) adapted to the required service quality, in terms of transmission error rate and transmission rate for the information transmission in question. This step of determining the transmission parameters is performed during the step denoted G_2 of the management method according to the invention .

When this determination step is performed, the transmission parameters, namely the number of carriers and the modulation, which are allocated to the transmission in question, are transmitted (step G_3) by the management unit 2172 on the one hand to the reception unit 2072 and on the other hand to the sending unit 2070 with a view to the sending of these parameters to the peripheral station SP_1.

In accordance with step R_1 of the reception method according to the invention, whose algorithm is shown in Figure 27, the reception unit 2072 receives the transmission parameters thus determined.

Returning to Figure 21, which details the reception unit 2072 of the base station, it can be seen that the transmission parameters which have been determined are directed to the two units 2130 and 2132. The number of carriers allocated to the communication station in question, having regard to the required service quality, is transmitted to the means 2130 of reconfiguring the number of carriers.

The modulation adapted to the transmission in question, having regard to the service quality required for it, is transmitted to the modulation reconfiguration means 2132.

Let it be considered, for example, that the Fourier transform operation performed in the unit 2124 (Figure 21) supplies 1512 points at the output, and let it be considered that the transmission management device and more precisely the determination means 2174 on the one hand indicate that, having regard to the required service quality, it is necessary to have 501 carriers and on the other hand identify the 501 useful outputs of the FFT circuit 2124.

Thus, in the example considered, out of the 1512 output points of the circuit 2124, only 501 have a significant value, and the means 2130 effect a reconfiguration of the number of carriers, selecting the 501 useful outputs of the circuit 2124.

Likewise, the information concerning the modulation adapted to the transmission in question enables the means 2132 to reconfigure the modulation applied to the future complex symbols 2146, on the one hand by selecting the adapted look-up table and on the other hand by acting on the parallel to serial conversion unit 2154 by supplying to said unit the number R according to which the binary data must be grouped.

When the reception unit 2072 of the base station has been reconfigured according to these transmission parameters, in accordance with step R_2 of the reception method according to the invention, said reception unit sends a reconfiguration confirmation message to the management unit 2172.

At the peripheral station SP_1, the transmission parameters transmitted over the incoming link denoted 2014 in Figure 24 are distributed on the one hand to the reception unit 2042 and on the other hand to the sending unit 2040 by means of the modem interface 2038.

As depicted in Figure 17, the transmission parameters are intended on the one hand for the means 2090 of reconfiguring the modulation to be allocated to the information transmission, and on the other hand to the means 2088 of reconfiguring the number of carriers to be allocated to the information transmission.

As a function of the received modulation parameters (type of modulation and level), the reconfiguration means 2090 act on the serial to parallel conversion unit 2098, supplying to it the number R according to which the binary data must be grouped, and select in the unit 2100 the look-up table adapted to the modulation under consideration.

As a function of the transmission parameters received from the management device 2172, namely the number of carriers and the number of the carriers to be considered, the reconfiguration means 2088 match the complex symbols 2106 (Figure 20) to the numbers of the inputs e_i, i = 0 to n, of the circuit 2092 (IFFT) which were supplied by the management device 2170.

The reconfiguration means 2088 in a sense switch the complex symbols 2106 onto the inputs corresponding to the appropriate carriers of the circuit 2092 (IFFT).

When the sending unit 2040 of the peripheral station SP_1 receives the transmission parameters determined by the management device 2170 of the base station SB, in accordance with step E_2 of the sending method according to the invention, and when the reconfiguration step according to these parameters has taken place (step E_3), the peripheral station SP_1 sends a reconfiguration confirmation message to the management device 2170.

The transmission management method according to the invention includes a step G_4 of receiving reconfiguration confirmation messages coming from the reception unit 2072 and from the peripheral station SP_1.

In accordance with step G_5 of this same method, the transmission management device according to the invention sends a transmission enable message to the reception unit 2072 and to the peripheral station SP_1.

In accordance with step E_4 of the method whose algorithm is depicted in Figure 25, the sending unit 2040 of the station SP_1 receives the send enable message coming from the management device 2170.

The peripheral station SP_1 then sends information in accordance with the adapted transmission parameters (step E_5) .

Where the transmission of information between the station SP_1 and the station SB ends, then step G_6 is followed by step G_7 (Figure 26).

In the contrary case, the means 2136 depicted in Figure 21 measure the error rate of the current information transmission and transmit the result of this measurement to the unit 2176 depicted in Figure 24 (step R_4 of Figure 27). Following step G_8, the unit 2176 receives this error rate measurement.

In accordance with step G_9, the unit 2176 analyses the measurement of the error rate of the current information transmission and compares the result of this analysis with the required service quality, in terms of transmission rate and transmission error rate.

If the result of this analysis does not meet the service quality required for the information transmission in question, then the transmission parameters must be modified once again.

In this case, step G_{10} is followed by steps G_2 to G_5 previously described.

The transmission management device according to the invention, denoted 2170, thereby determines new transmission parameters (number of carriers and modulation) and transmits them to the reception unit 2072 and to the peripheral station SP_1.

The peripheral station SP_1 receives from the transmission management device a message reconfiguring the parameters of the current transmission (step E_6). In this case, steps E_3 to E_5 of the sending method are performed once again.

At the same time, the reception unit 2072 receives the message reconfiguring the parameters of the current transmission (step R_5) and the previously described steps R_2 to R_4 are performed once again.

In so far as it is determined that the parameters of the current transmission should not be modified (step G_{10}), then step R_5 is followed by step R_6 (Figure 27) during which a test is carried out to determine whether the reception unit 2072 receives an end of transmission.

If the transmission is not terminated, then the previously described steps R_3 and R_4 are performed once again .

Because of this, with regard to the transmission management method according to the invention, step G_{10} is followed by steps G_8 and G_9, which are also performed using a new measurement of the transmission error rate made by the reception unit 2072.

This measurement of the error rate of the current transmission and the corresponding adaptation of the number of carriers and of the modulation so as to satisfy the required service quality criteria are performed continuously during the information transmission in question.

Returning to Figure 25, when no message reconfiguring the current transmission parameters is received from the management device 2170, then step E_6 is followed by step E_7 during which a test is formed to determine whether the sending unit 2040 of the peripheral station SP_1 is requesting an end of transmission.

If an end of transmission is not requested, then step E_7 is followed by steps E_5 and E_6.

On the other hand, if the sending unit requests an end of transmission, then the step E_7 is followed by step E_8, during which the peripheral station SP_1 sends an end of transmission message by means of the incoming radio link 2012 to the transmission management device according to the invention 2170. The reception unit 2072 also receives the end of transmission message and step R_6 is followed by step R_7, putting an end to the transmission.

Step G_6 performs a test on the end of transmission and is followed in this case by step G_7 putting an end to said transmission.

The peripheral communication station SP'$_1$ depicted in Figure 28 concerns a second embodiment of the invention.

In this Figure, all the elements which remain unchanged compared with those of Figure 15 are repeated and keep the same references.

The peripheral station SP'$_1$ has a data source 2020 and an information sending and reception device 2200.

This sending/reception device 2200 has a data processing unit 2202 which comprises a central unit denoted CU and referenced 2026, a bus interface 2032 and a bus 2034 which connects the data source 2020 to said interface 2032, the data processing unit 2202 also comprises a modem interface 2038, a temporary data storage means (RAM) 2204 and a permanent storage means (ROM) denoted 2206.

The sending and reception device 2200 also includes an information sending unit 2208 connected to a radio module 2044, which is equipped with an antenna 2046.

The sending and reception device 2200 also includes a reception unit 2210 connected to the radio module 2044 and a modem interface 38.

As depicted in Figure 28, the bus interface 2032, the central unit 2026, the modem interface 2038 and the storage means 2204 and 2206 are all connected by a bus 2036.

In this embodiment, the functionalities of the sending and reception methods according to the invention are implemented by means of computer programs denoted respectively Progr E and Progr R.

The program which implements the sending method according to the invention is placed in a memory area denoted 2206a of the storage means 2206. The instructions of this computer program correspond to steps E_1 to E_8 of the algorithm depicted in Figure 25.

The program which implements the information reception method according to the invention is placed in a memory area denoted 2206b of the storage means 2206.

The instructions of this computer program correspond to steps R_1 to R_7 of the algorithm depicted in Figure 27.

In this embodiment, the sending 2208 and reception 2210 units include the same elements as the sending 2040 (Figure 17) and reception 2072 (Figure 21) units, with the exception of the respective units 2086 (Figure 17) and 2138, which are not repeated in said units 2208 and 2210.

This is because the functionalities implemented in these units are now implemented by the respective computer programs ProgrE and ProgrR.

The storage means 2204 has several registers denoted 2204a to 2204f, which contain different variables used during the execution of the instructions of the previously mentioned computer programs.

Thus the register 2204a contains a variable called number of carriers and denoted NSP. The register 2204b contains a variable called modulation and denoted Mod. The register 2204c contains a variable called transmission error rate and denoted TE. The register 2204d contains a variable called passband (this also corresponds to the transmission rate) and denoted BW. The register 2204e contains a variable called service quality and denoted QoS.

The register 2204f contains a variable called measurement, denoted Mes, and which corresponds to the result of the measurement of the error rate of a current transmission, effected in the unit 2210.

The variables TE, BW and QoS are used during step E_1 of the computer program Progr E.

The transmission parameters denoted NSP and MoD are used during steps E_2, E_3 and E_6 of the computer program Progr E and during steps R_1 and R_2 of the computer program Progr R.

Figure 29 illustrates a second embodiment of a base communication station SB' according to the invention. This station has a data source 2050 and a transmission management device 2212.

This transmission management device 2212 also fulfils the sending and reception functions. The transmission management device 2212 has a data processing unit 2214 which comprises a central unit denoted CU and referenced 2056, a bus interface 2062 and a bus 2064 which connects the data source 2050 to said bus interface, a modem interface denoted 2068, a temporary data storage means (RAM) denoted 2220 and a permanent storage means (ROM) denoted 2222.

A bus 2066 connects the central unit 2056, the bus interface 2062, the modem interface 2068 and the storage means 2220 and 2222.

The transmission management device according to a second embodiment of the invention also has a sending unit 2224 connected to a radio module 2076, which is equipped with an antenna 2078.

The sending unit 2224 is also connected to the modem interface 68.

The transmission management device 2212 also has a reception unit 2226 which is on the one hand connected to the radio module 2076 and on the other hand to the modem interface 2068.

In this embodiment, the functionalities of the transmission and reception management method according to the invention are implemented by means of computer programs denoted Progr G and Progr R.

The permanent storage means 2222 has two memory areas denoted 2222a and 2222b, which contain respectively the programs Progr G and Progr R.

The instructions of the program Progr G correspond to steps G_1 to G_{10} of the algorithm depicted in Figure 26.

The instructions of the program Progr R correspond to steps R_1 to R_7 of the algorithm depicted in Figure 27.

The temporary data storage means 2220 contains several registers denoted 2220a to 2220f, each containing a different variable with is used

during the execution of the different instructions of the above-mentioned computer programs.

The variables denoted NSP, Mod, TE, BW, QoS and Mes are the same as those described with reference to Figure 28 and are therefore not explained any further here. These variables are respectively contained in the registers 2220a to 2220f of the temporary data storage means 2220.

The variables TE, BW and QoS are used during step G_1 of the program Progr G. The variables denoted NSP, Mod are used during steps G_2 and G_3 of the program Progr G.

The first variables cited TE, BW and QoS are also used during steps G_9 of this same program. The variable Mes was used during steps G_8 and G_9.

The transmission parameters represented by the variables NSP and Mod are used during step R_1 of the computer program Progr R. The variable Mes is used during the step denoted R_4 of the computer program Progr R.

It should be noted that the sending 2224 and reception 2226 units of the base station SB' are identical to the units 2040 and 2072 depicted respectively in Figures 17 and 21, except for blocks 2086 and 2138, which are not repeated.

This is because the functionalities provided by the units are now implemented by the computer programs.

The permanent storage means also contains a memory area denoted 2222c which contains a computer program Progr E for implementing the sending method according to the invention.

The instructions of this program correspond to steps E_1 to E_8 depicted in the algorithm in Figure 25. The variables contained in the registers 2220c, 2220d, 2220e are used during step E_1 of the programme Progr E. The variables contained in the registers 2220a and 2220b are used during steps E_2, E_3 and E_6 of the computer program Progr E.

According to a variant which is not shown, the functionalities of the sending 2224 and reception 2226 units of the base station SB' are

implemented by one of the computer programs stored in memory areas of the storage means 2222.

In order to illustrate the possible choices of reconfiguring the modulation and the number of carriers in order to guarantee a given service quality, the parameters of the OFDM modulation which follow will be taken as an example, and these are:

- number of carriers = 1512 or 6048 useful carriers,
- 3 modulation levels: 4QAM, 16QAM, 64QAM,
- 3 coding ratios: 1/2 ; 2/3 ; 3/4 ; 5/6 ; 7/8,
- guard time: 1/4, 1/8, 1/16, 1/32 of the duration of the OFDM symbols.

The coding ratio is defined as being the ratio between the number of useful information items and the number of redundant information items added by the coding in order to make the information transmission more reliable. A coding ratio of 3/4 means that there are three useful information items for one redundant information item.

The guard time for its part defines the interval of time separating two consecutive transmissions of OFDM symbols.

By modifying all these parameters, different possible global rates are obtained. Thus, if the coding ratio is fixed at 7/8 and the guard time at 1/32, there are obtained, as a function of the QAM-type modulation level used, the following global transmission rates:

- 4 QAM → 10.56 Mbit/s (all the carriers are used)
- 16QAM → 21.11 Mbit/s (all the carriers are used)
- 64QAM → 31.67 Mbit/s (all the carriers are used)

Consequently, with 1512 useful carriers, if it is wished to allocate a useful rate of 3.5 Mbit/s to an information transmission, there are the following three solutions

Solution	Useful rate	Modulation	Number of carriers

1	3.499 Mbit/s	4QAM	501
2	3.504 Mbit/s	16QAM	251
3	3.497 Mbit/s	64QAM	167

with the useful rate expressed in the form:

Useful rate = (global rate/1512) x number of carriers allocated.

Solution 1 uses a very robust 4QAM modulation which can guarantee transmission with a low error rate, but in return close on one third (501/1512) of the carriers will be necessary.

Solution 2 uses a less robust 16QAM modulation but requires only one sixth of the carriers.

Solution 3 uses one ninth of the carriers with a scarcely robust modulation.

In order to guarantee the transmission rate of 3.5 Mbit/s, the management device 2170 or 2212 according to the invention therefore has a choice between these three solutions.

Its choice is made according to the acceptable error rate for the transmission concerned.

This error rate is related to the service quality required with the transmission request.

It might be thought that solution 1 will always be the most advantageous solution whatever the service quality requested.

However, the function of the management device according to the invention being to use the radio resources as effectively as possible, it would be disadvantageous in terms of radio resources management to use solution 1 whilst the current transmission conditions make it possible to choose solution 3.

It will easily be understood that, if solution 3 is chosen for all the peripheral stations SPi communicating with the base station SB, it will be

possible to have simultaneously nine transmissions each with a transmission rate of 3.5 Mbit/s whilst solution 1 would allow only three transmissions.

When the radio resources of a network become limited, the management device 2170 or 2172 according to the invention will have to make compromises between the transmission parameters determined for a given information transmission and what it can actually offer. These compromises depend on the required service qualities.

For example:

- a service quality A defines a fluctuation in the required useful transmission rate of +/- 20 % and an error rate threshold in bits transmitted of 10^{-6}.

A service quality B defines a fluctuation in the required useful transmission rate of +/- 5 % and an error rate threshold in bits transmitted of 10^{-5}.

A service quality C defines a fluctuation in the required useful transmission rate of +/- 30 % and an error rate threshold in bits transmitted of 10^{-8}.

A service quality D defines a fluctuation in the required useful transmission rate of +/-1 % and an error rate threshold in bits transmitted of 10^{-8}.

Let it be assumed now, for example, that the peripheral stations SP_1 and SP_2 of Figure 14 have required the same transmission rate and the same error rate threshold and are disposed at different distances with respect to the base station SB.

For example, the peripheral station SP_1 is closer to the base station than the station SP_2.

The transmission of information between SP_1 and SB can then use a modulation of low robustness (eg 64 QAM) and a small number of carriers.

On the other hand, the transmission of information between SP_2 and SB, because of the distance which separates them, will therefore on the one hand have to use a very robust modulation (4QAM) in order to obtain an error

rate equivalent to that of the transmission between SP_1 and SB, and on the other hand will require a number of carriers appreciably greater than that allocated to the said transmission between SP_1 and SB.

If the management device according to the invention cannot allocate a sufficient number of carriers, the information transmission rate between SP_2 and SB will be decreased.

If this rate becomes less than the minimum rate tolerated by the service quality requested by station SP_2, the management device will have to reduce the number of carriers allocated to the transmission of information between SP_1 and SB in order to satisfy transmission between SP_2 and SB.

This example presents the important role played by the management device in the optimum management of the radio resources of a network.

In another example, the peripheral stations SP_1 and SP_2 of Figure 14 do not require the same service quality, the service quality requested by SP_1 requiring a number of carriers much greater than that required by SP_2.

In such a case, the compromise established by the management device according to the invention is simple since the carriers not used for the transmission of information between SP_2 and SB are allocated to the transmission of information between SP_1 and SB.

It should also be noted that, in addition to the service qualities required for the transmission of information between the peripheral stations SP_i, i = 1, ..., N, and the base station SB, priorities can be allocated to these information transmissions according for example to the nature of the information to be transmitted and the applications envisaged.

According to this possibility, one of the information transmissions between a peripheral station, for example SP_1 and the base station SB, is allocated a higher priority than the transmissions between the other peripheral stations and the base station SB, and if this same transmission needs, because of its required service quality, a number of carriers greater than that previously allocated, then, whatever the service qualities required for the other

transmissions, the necessary number of carriers will be taken from one or more of these other transmissions.

Provision can also be made for the number of carriers necessary to the transmission of information with the highest priority to be taken from the information transmission with the lowest priority.

By way of example, Figure 30 depicts an ODFM symbol with 1512 carriers distributed over three transmissions of information between SP_1, SP_2, SP_3 and SB.

The transmission between SP_1 and SB is effected with a transmission rate of 3.5 Mbits/s for a number of carriers of 167 and a 64QAM modulation.

The transmission between SP_2 and SB is effected with a transmission rate 3.5 Mbits/s for a number of carriers of 501 and a 4QAM modulation.

The transmission between SP_3 and SB is effected with a transmission rate of 500 Kbit/s for a number of carriers of 72 and a 4QAM modulation.

Thus, out of the 1512 carriers, 772 are not used for the three information transmissions in question but can be allocated subsequently if the required qualities and/or the transmission conditions on the communication channels are changed.

The scope of the present invention is not limited to the details of the forms of embodiment discussed above by way of example but extends, on the contrary, to changes within the grasp of a man of the art. It is clear, for example, that the invention extends to a process for transmitting data over a transmission channel using a multi-carrier type of modulation, a significance being attributed to each data element or group of data elements for transmission, and the different classes of data being transmitted using modulators favoring either the bit rate or the bit error rate, or again, the energy transmitted.